[x] ORIGINAL [ ] REVISION NO. ______

Project No. A-3325 DATE 9/16/82

Project Director: C. H. Cash ~~XXXXX~~/Lab RAIL/OOD

Sponsor: Raytheon Company, Missile Systems Division, MA

Type Agreement: Purchase Order No. 71-0533-BD-97007

Award Period: From 7/20/82 To ~~11/5/82~~ ~~12/31/82~~ 5/15/83 (Performance) ______ (Reports)

Sponsor Amount: $98,390 (including $5,000 patent/data rights fee) Contracted through:

Cost Sharing: None GTRI/~~EXX~~

Title: Millimeter Radar Backscatter Data Collection

ADMINISTRATIVE DATA OCA Contact William F. Brown x-4820

1) Sponsor Technical Contact:

2) Sponsor Admin/Contractual Matters:

G. E. Williamson, Buyer
Raytheon Company
Missile Systems Division
Mail Station M13-32
Hartswell Road
Bedford, MA 01730
(617) 274-7100, Ext. 2108

Defense Priority Rating: None

Security Classification: None

RESTRICTIONS

See Attached --- Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with None proposed or anticipated

COMMENTS:

SEP 1982
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Research Reports
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Computer Input
Project File
Other GTRI

FORM OCA 4:781

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date June 29, 1983

Project Title: Millimeter Radar Backscatter Data Collection

Project No: A-3325

Project Director: C. H. Cash

Sponsor: Raytheon Company, Missile Systems Division, MA

Effective Termination Date: 12/30/82 (Task I) 5/15/83 (Task II)

Clearance of Accounting Charges: 12/30/82 (Task I) 5/15/83 (Task II)

Grant/Contract Closeout Actions Remaining:

NONE

- [ ] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [ ] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Assigned to: RAIL-OOD (~~School~~/Laboratory)

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Computer Input
Project File
Other Cash

FORM OCA 10:781

Georgia Institute of Technology
ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA 30332

September 14, 1982

Raytheon Company
Missile Systems Division
Hartswell Road
Bedford, Massachusetts 01730

Attention: Mr. E. R. Hiller
Mail Station M13-32

Subject: Monthly Progress Letter and Cost Report for August 1982, Purchase Order #71-0533-B0-97007, "Millimeter Backscatter Data Collection."

Gentlemen:

1. The preliminary test plan for data collection at the MICOM F1 test stand was completed and reviewed with Raytheon. Raytheon comments are being collated and the test plan revised.

2. An agreement was reached with MICOM for the use of the F1 test stand and tank targets.

3. The 95.5 GHz transmitter and modulator modifications have been completed and tested.

4. The radar waveguide modifications, STALO mounting, circuit cards modifications, additional power supplies, radar circuit card modification, mount and positioner tests and connector panel modifications are completed.

5. The radar receiver is complete except for two each IF amplifiers, step attenuators and filters which are on order from vendors.

6. Integration and test of the radar at Georgia Tech, installation on the MICOM F1 test stand, and initiation of data collection will proceed during September.

Cost Report

Project Duration	3½ months
Months into Project	1 month

Funds Contracted	$93,390
Funds Expended	$24,308
Funds Remaining	$69,082

Respectfully submitted,

[redacted]

Carlton H. Cash
Project Director

APPROVED: [redacted]

Jerry L. Eaves
Associate Director
Radar & Instrumentation Laboratory

saw

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
A Unit of the University System of Georgia
Atlanta, Georgia 30332

November 24, 1982

Raytheon Company
Missile Systems Division
Hartswell Road
Bedford, Massachusetts 01730

Attention: Mr. E. R. Hiller
Mail Station M13-32

Subject: Monthly Progress Letter and Cost Report for October 1982, Purchase Order #71-0533-ED-97007, "Millimeter Backscatter Data Collection."

Gentlemen:

1. The radar and instrumentation was initially installed on the MICOM/NASA F1 test stand on October 4, 1982. However, due to a failure of the vertical channel RF mixer which was returned to the vendor for repair the radar became operational on October 11, 1982.

2. During October data were recorded in accordance with the test plan of Enclosure 1 on the following targets:

M48 Tank
2½ ton truck
Automobile
Grass clutter
Tree clutter
Tree line clutter
Trihedrals
Dihedral
Two trihedrals spaced 1 meter in range

In addition, data was taken on the Georgia Tech instrumentation van and a complex steel tower. The text matrix of Enclosure 1 was approximately 75% completed.

3. An interface between the Honeywell 5600 recorder and the Georgia Tech VAX computer was designed and fabricated. The computer was programmed to digitize the recorded data. The Honeywell recorder was returned to Georgia Tech so that satisfactory data content and computer interface can be verified.

4. The data matrix of Enclosure 1 will be completed and data digitizing will proceed during November.

Cost Report

Project Duration	4 months
Months into Project	3 months
Funds Contracted	$93,390
Funds Expended	$78,966
Funds Remaining	$14,424

Respectfully submitted,

[redacted]
Project Director

APPROVED: [redacted]
E. K. Reedy, Director
Radar & Instrumentation
Laboratory

saw

Enclosure

Millimeter Radar Backscatter
Data Collection
Test Plan

Prepared For

Raytheon Company
Missile Systems Division
Bedford, Masachusetts

Prepared By

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

August 1982

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LIST OF FIGURES

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SECTION 1
INTRODUCTION

1.1 Program Scope

The Engineering Experiment Station of the Georgia Institute of Technology will perform a radar backscatter data collection for the Raytheon Company, Missile Systems Division in support of its research and development programs. Target and ground clutter radar backscatter data will be recorded by Georgia Tech at a tower facility at Redstone Arsenal, Alabama during the period of September through October 1982. Program deliverables include a set of computer compatible, magnetically recorded tapes that contain the radar backscatter signatures.

Georgia Tech wil utilize an instrumented 95 GHz polarization agile radar system developed at Georgia Tech to obtain the required data. The data collection effect will be supported by Georgia Tech personnel at the tower site along with MICOM personnel to assist in logistics and targets.

1.2 General Test Description

The 95 GHz radar and all supporting equipments will be assembled and tested at the Georgia Tech facilities prior to shipment to Redstone Arsenal. Upon completion of these tests, the equipment will be transported to Redstone Arsenal where they will be installed on the upper level of the F1 Test Tower located in the NASA West Test Area. The equipment will be installed in the test laboratory atop the F1 Tower which affords a view of the test area to the west of the F1 Tower. The radar system and ancillary equipments will be installed and calibrated. Preliminary measurements and on site analysis will be conducted to insure that the radar and instrumentation systems are functional.

A series of target and clutter measurements will be conducted using the 95 GHz radar in its frequency agile mode. The recorded data will include the simultaneous measurement of horizontally and vertically polarized backscatter amplitudes and I and Q polarimetric phase. The backscatter data will be sample/held and boxcovered at the radar prf. This analog data will be recorded on fm magnetic tape for future processing. A calibration of the radar will accompany each set of measurements to insure the accuracy of the recorded data. This calibration will consist of an injected RF signal into the radar front end, measurement of the transmitter parameters and radar measurement of calibrated targets.

The recorded data will be returned to the Georgia Tech facilities in Atlanta where it will be digitized and placed in a format compatible with Raytheon's computing facilities.

SECTION 2
MEASUREMENT EQUIPMENT DESCRIPTION

2.1 95 GHz Radar System

The 95 GHz Radar System to be utilized in this program has been developed by Georgia Tech as an instrumentation grade radar system. The radar is designed to be flexible, easily calibrated and easily operated in multiple modes. Table 1 is a listing of the basic parameters of the radar system which is depicted in block diagram form in Figure 1. The radar transmitter consists of a 95 GHz Extended Interaction Oscillator (EIO) which has a peak power output of 1KW, a pulse width of 100 nanoseconds and variable prf. The transmitter path is configured to allow transmission of linear or circular polarizations. The change is made by waveguide switches as noted in the block diagram. A ferrite switch is used to select which of the waveguide switches is fed the transmitter signal. In the linear polarization mode, the rf signal couples through the switch, the circulator and to either the horizontal or vertical port of the dual mode coupler at the antenna. In the circular polarization mode, the transmitter signal is fed to the hybrid ring which splits the power between channels (H and V), through the waveguide switches to the orthomode coupler. The amplitude and phase of the signals are adjusted to produce a circularly polarized transmitted wave. The switch is electronically switchable and can be used to switch between H and V or RC and LC on a pulse-to-pulse basis.

The receiver consists of a dual polarized receiver (H and V). A circulator and switches are used to isolate the transmitter and receiver during transmit time. Receiver recovery time is approximately 0.75 microseconds. Precision attenuators are included in the receiver lines for calibration of the receiver. The superhetodyne receivers employ a set of balanced mixer/preamps with a noise figure of 10 dB (DSB) and have an IF output of 2 to 4 GHz. The output of the H, V IF's are fed to the IF Polarization processor.

Antenna beamwidths can be easily changed by the removal and addition of various antennas. Antennas to be used on this program have beamwidths of 18°, 3° and 0.7°. Waveguide couplers are used at the antenna to allow the transmitter parameters to be measured and allow rf calibration signals to be fed into the receiver front end.

The radar transmitter was modified for this program to allow the EIO to operator in a frequency agile mode. This has been accomplished by adding a 30 hertz triangular modulation to the EIO beam voltage. The radar transmitter will be operated at a prf of

TABLE 1 95 GHZ RDAR PARAMETERS

Center Frequency	95.5 GHz
Freq. Agile Bandwicth	300 MHz
Transmitter	1KW EIO
Pulse Width	100 nsec
PRF	4882 Hz
Freq. Steps	64
Antenna Beamwidths	18°, 3°, 0.7°
Transmit Polarization	V or H, RC or LC
Frame Time	16 msec.
Receiver Type	Dual Polarized H, V
Receiver Noise Fig.	10 dB DSB
Receiver Sensitivity	-81 dBm
IF Processing	H, V I and Q Polarimetric Phase H, V amplitude
Data Output	Box Car S/H (4 channels)

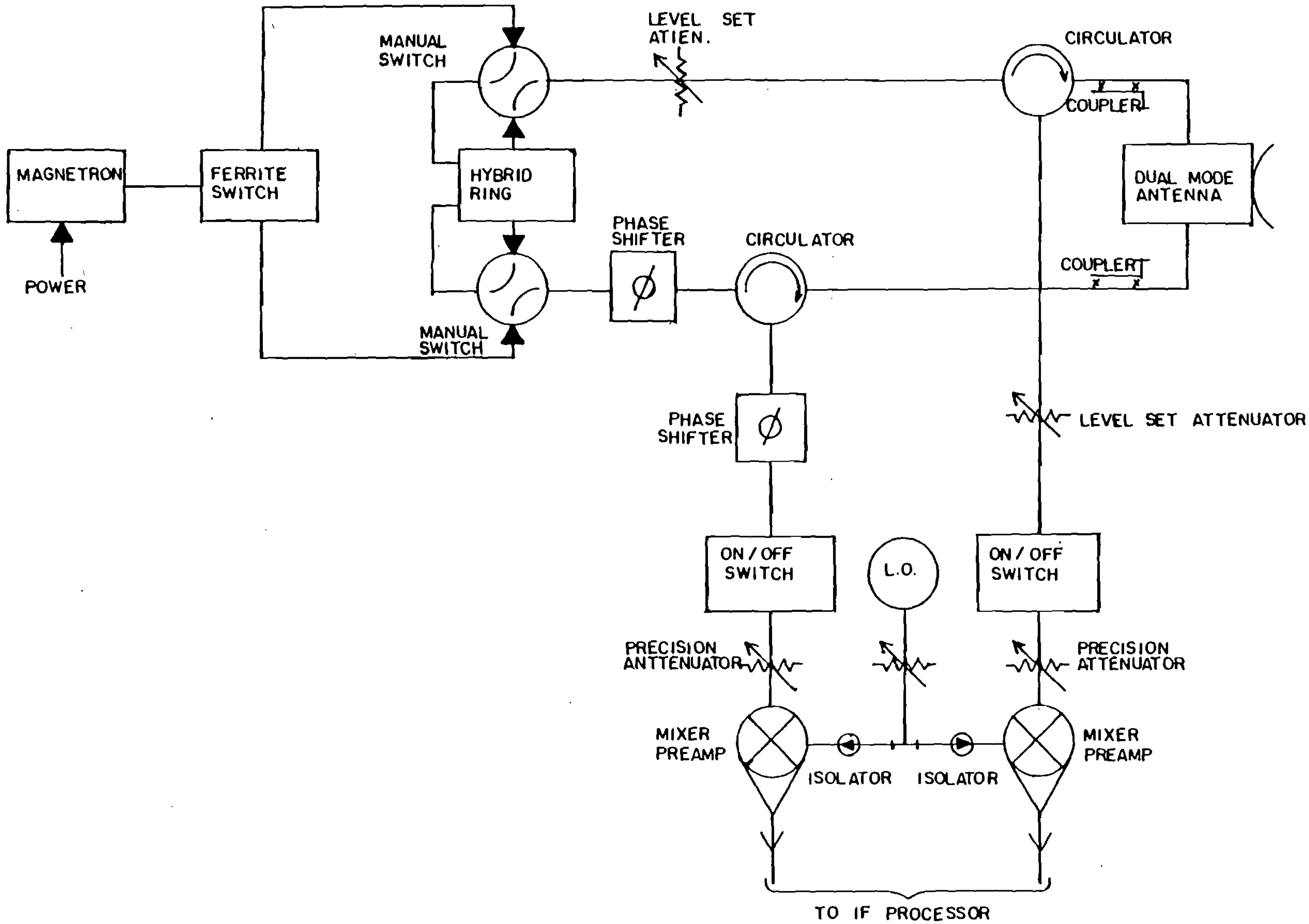


Figure 1. Block Diagram of 95 GHz Radar

4882 hertz. This would correspond to approximately 78 steps of approximately 3.84 MHz, for a transmitter deviation of 300 MHz. The traingular modulation is not synchronous with the prf but the triangular modulation waveform is recorded on the fm tape, along with a prf reference.

2.2 IF Polarimetric Processor

The primary features of this measurement program is to obtain I and Q polarimetric data. A separate IF processor was assembled for the 95 GHz radar to accomplish this. Figure 2 is a block diagram showing the mechanization of the IF processing.

The 2-4 GHz IF from the mixer preamps is fed to paralleled H, V channels. The IF frequency will be centered at 3 GHz. The IF processing consists of additional gain, IF attenuators to allow the gain to be set for each measurement setup, an IF filter to set the receiver bandwidth and the hybrids mixers and detectors used to generate the amplitude detection of the H and V channels and the polarimetric phase. The RF phase shifter in the receiver line will be used to establish the 90° phase relationship been H and V and the I and Q relationship will be fixed in the fabrication of the IF processor.

The four data outputs will be fed to the data acquisition circuitry in the radar. This consists of a 7 MHz low pass filter, amplifier, sampler and box car generator. The boxcarred data (at the prf rate) is then fed to the fm tape recorder for recording.

2.3 Ancillary Equipment

The equipment setup for the tower installation is shown in Figure 3. The 95 GHz radar is installed on an elevation over azimuth turntable which allows the radar to be remotely positioned. A closed circuit TV camera is boresighted to the antenna line of sight so that the pedestal operator can point the radar at the desired target. The turntable also has a digital readout with a 0.1° resolution. The remote control for the radar, pedestal, TV equipment and tape recorders will be co-located for operator convenience.

The radar output will be displayed on an oscilloscope in an "A scope" format. A second TV camera will be used to record the "A scope" display. A video mixer will be used to implement a split screen display so that the target scene and "A scope" video can be viewed simultaneously. In addition a boresight indicator and time code will be encoded on the video, provided such equipments are available during the measurement program.

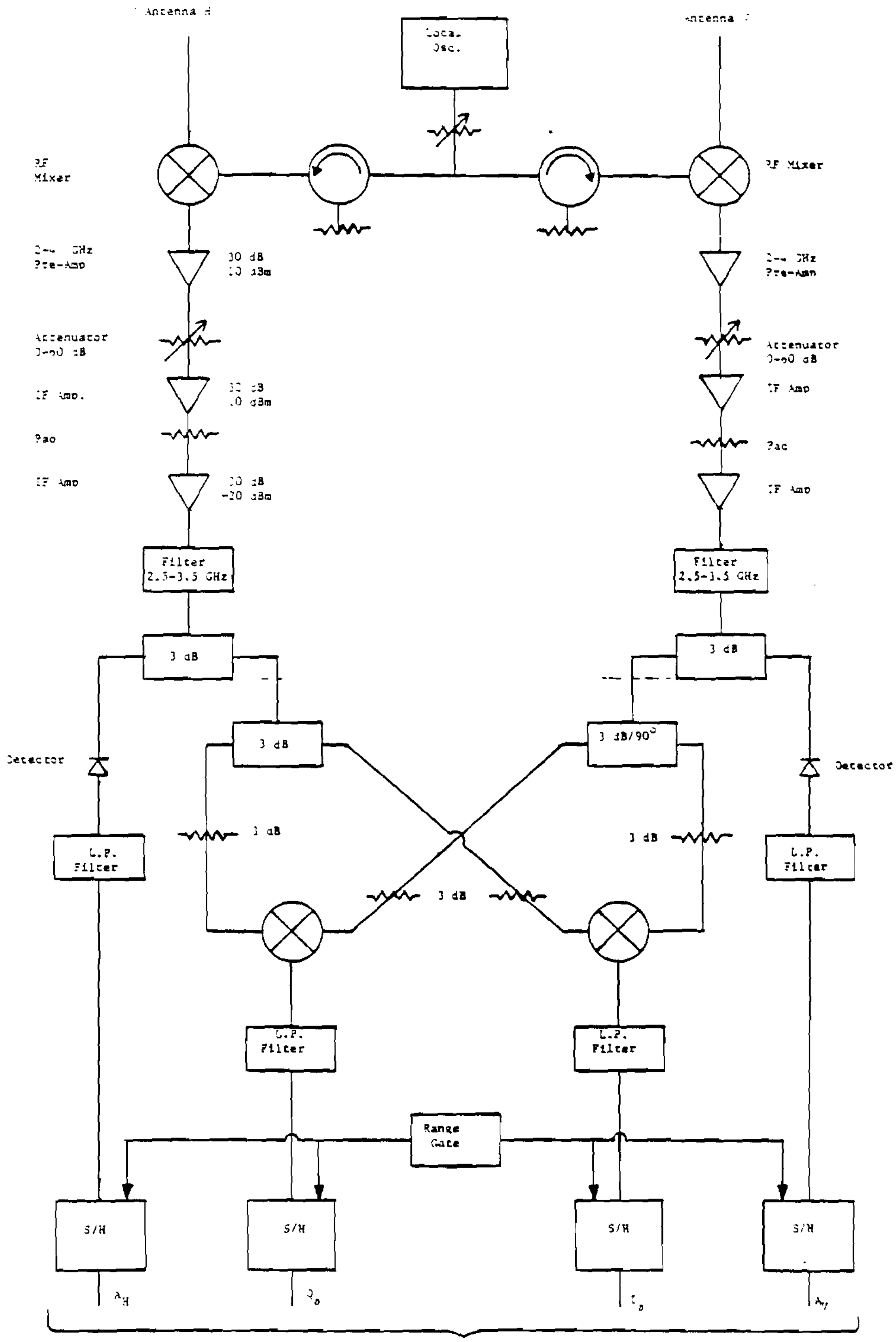


Figure 2. Block Diagram of IF Processor

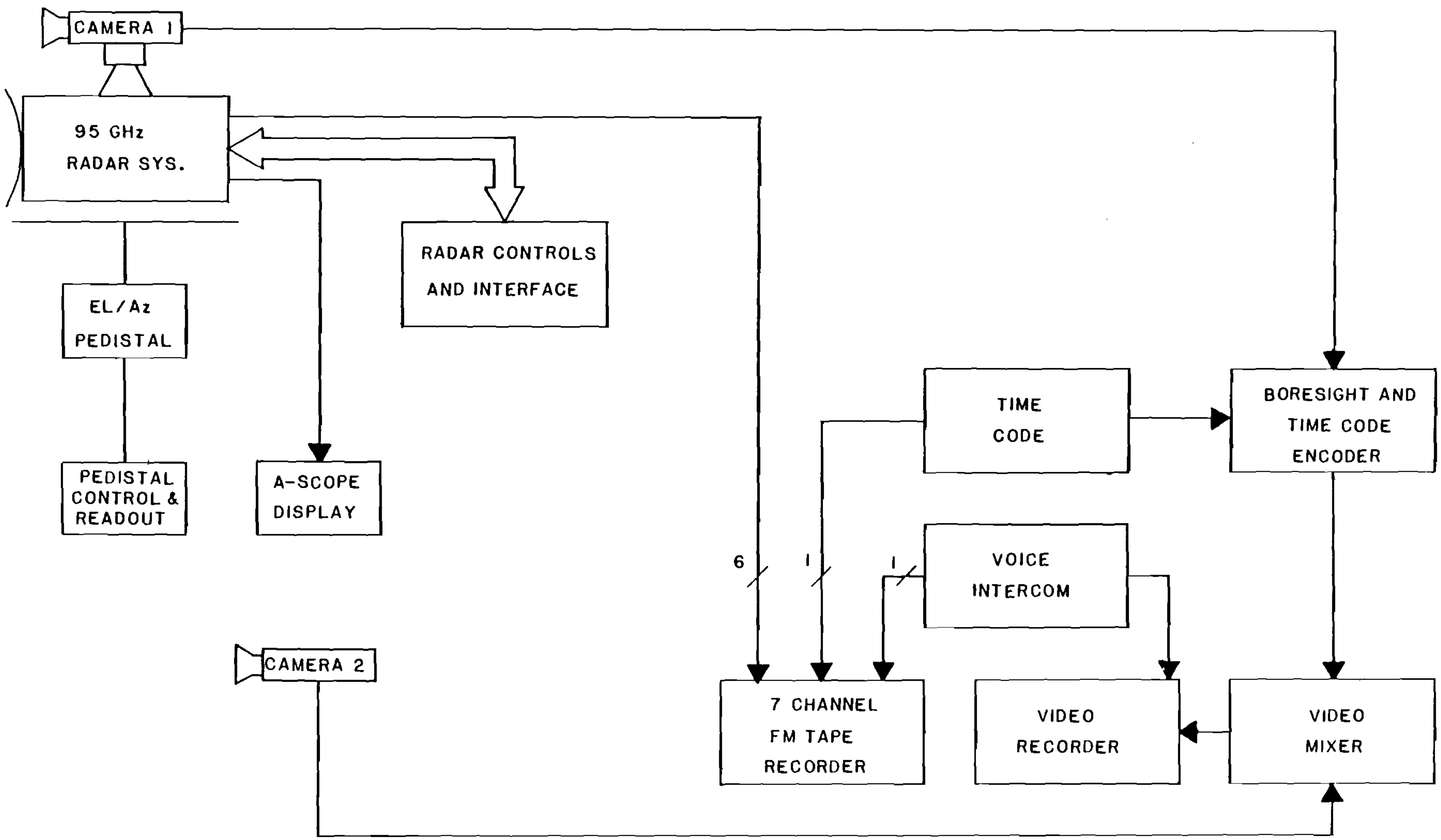


Figure 3. Measurement Equipment Configuration

The radar boxcar video and reference signals will be recorded on a seven channel Honeywell 5600 tape recorder. This data will be recorded at 15 1/2 ips in a wideband format. The TV video will be recorded on available color TV recording euqipments. A voice (intercom) channel will be recorded on both TV and tape.

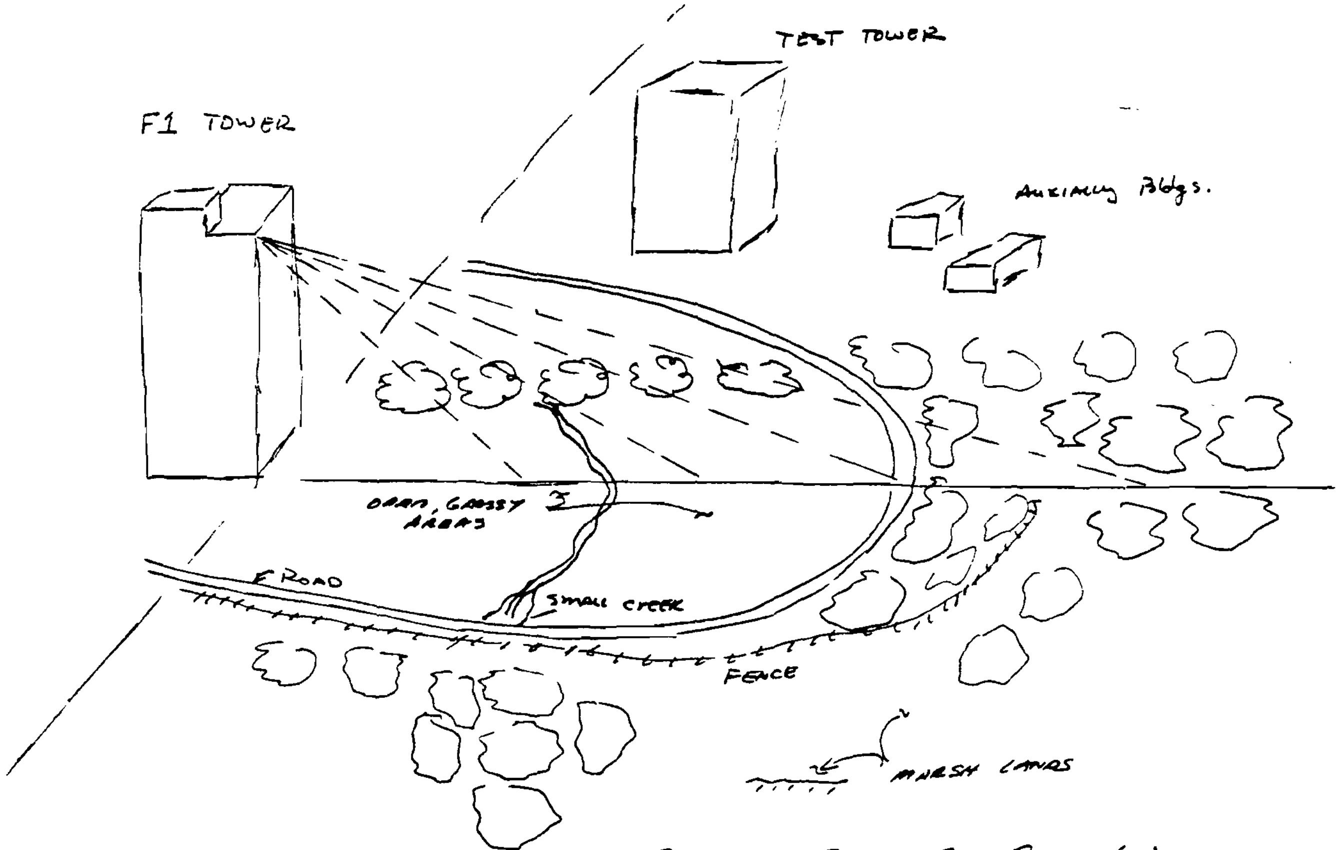
Additional equipment such as calibrated reflectors, boresight instrumentation, oscilloscopes, etc. will be provided by Georgia Tech as required to complete the data acquisition process. A hardware spectrum analyzer and correlator will be used to produce the on site verification of the radar performance and recorded data.

SECTION 3
TEST SITE FACILITIES DESCRIPTION

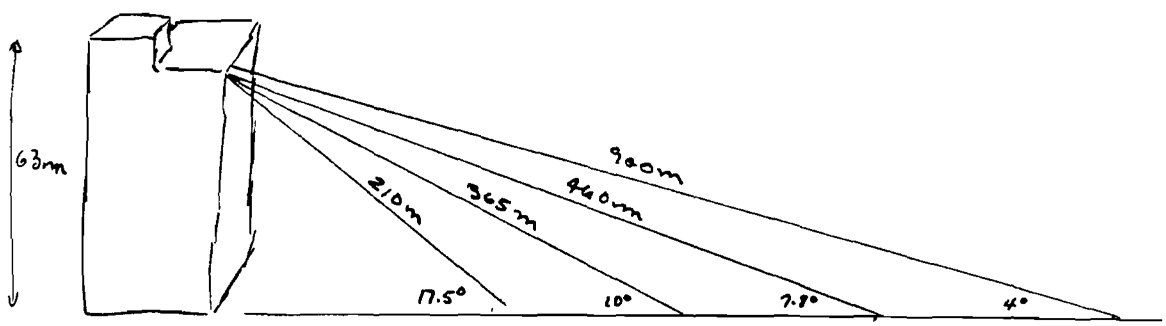
3.1 MICOM F1 Tower Facilities

The F1 Tower is a 63 meter tall static test stand used in the testing of rocket engines. The tower is quite massive, in excellent condition and is no longer used for rocket testing. The tower is located in the West Test Area of the NASA facilities at Redstone Arsenal, Alabama. The upper level of the tower has been equipped with a 12 foot x 14 foot x 8 foot building with exposure to the west. This allows the use of the grass range area that extends 1500 feet to the west of the tower for positioning of targets. This view affords a view of both clear grassy areas and heavily wooded terrain.

The tower has a small personnel elevator that can be used to carry equipment to the top. The building is equiped with air conditioning and heat and has 6-20 amps 120 V 60 Hz circuits available for external equipments. The elevation layout showing the range and depression angles to possible measurement sites is shown in Figure 4. A photograph of the F1 Tower is shown in Figure 5 and a view of the test range from the top of the tower is shown in Figure 6.



General Site Configuration



F1 Tower Geometry

FIGURE 4 SITE PLAN F1 TOWER

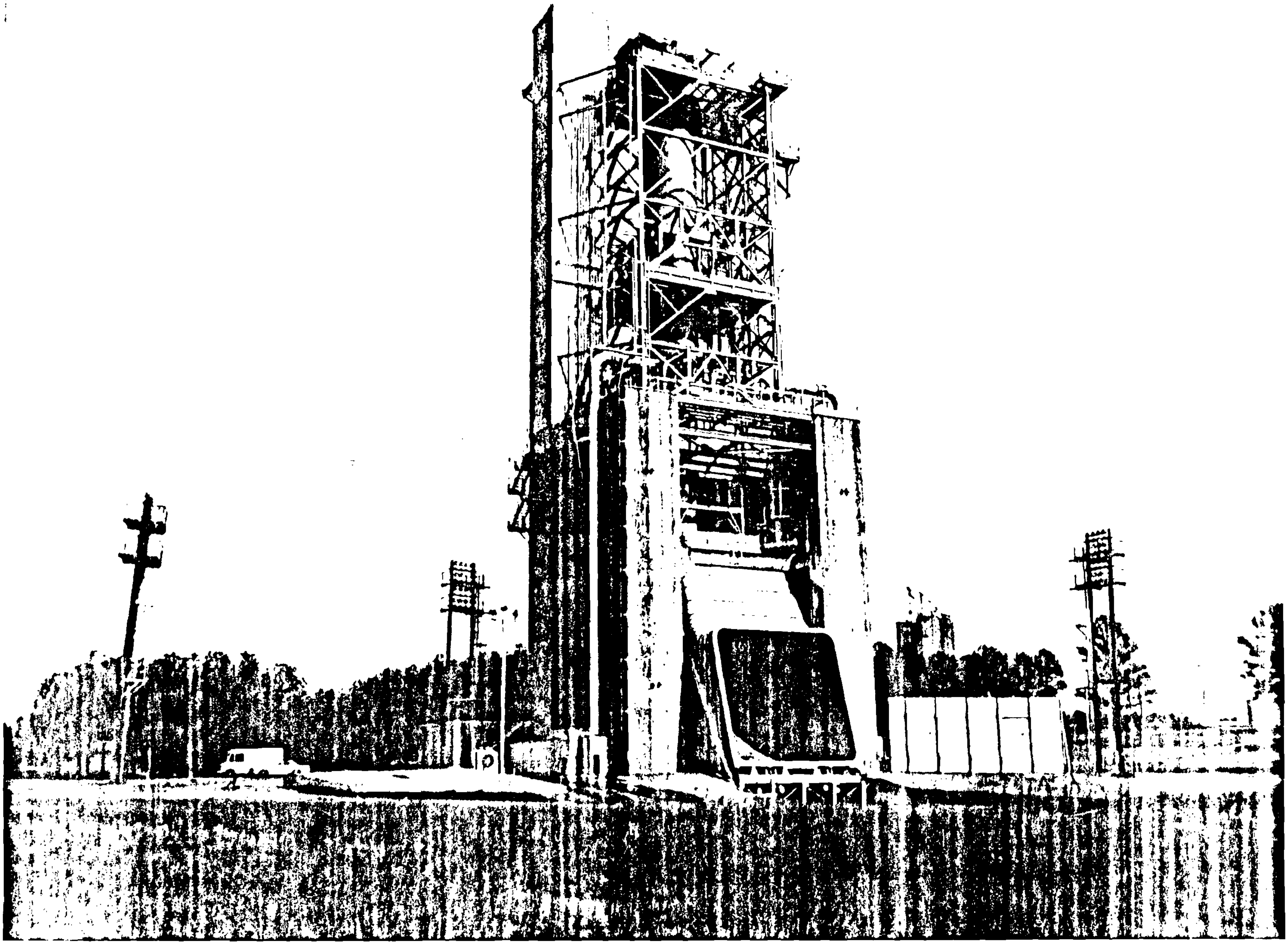


FIGURE 5 F1 TOWER

FIGURE 6 TEST RANGE AT F1 TOWER

SECTION 4
MEASUREMENT TECHNIQUE

4.1 General Measurement Procedure

The 95 GHz radar and associated instrumentation will be set up and calibrated on the F1 Tower as described in previous sections. The configuration of the radar will remain fixed throughout the measurement program with the exception of changes in antenna beamwidths. A test matrix of the measurements to be performed for clutter and targets are listed in Tables 2a, 2b and 3. The purpose of the matrix is to provide a guide as to the exact measurements to be performed during the test program. The matrix designates the location by the slant range to the target area (actual bearings will be determined during installation), the type of target or clutter desired by the measurement, the target aspects angle, transmitter polarization and antenna beamwidth. Unless indicated, all combinations of parameters listed for a particular line of measurements will be conducted.

A detailed data measurement log will be prepared, such as shown in Figure 7, for use in record keeping. This log will be referenced to the video and fm tape by IRIG time code. In addition, the start time, run number, all radar parameters, target description and stop time will be contained on the voice channels of the video and fm tape, for each individual data run. Data on weather, ground water, rain etc. will be included in the log.

A calibration sequence will be followed at the beginning and ending of each test segment and shall be done at least twice daily. One calibration at the beginning of the test measurements (or day) and a second calibration at the end of the measurements (or day). These calibrations include injection of test signals into the receiver and the measurement of standard corner reflectors, and diplanes. A test measurement log is prepared before the measurements of the day. The target areas to be used for the day are established and calibration of the radar completed prior to data taking. The radar is then boresighted to the target and/or target areas in accordance with the sequence defined in the measurements matrix. All data are recorded on fm magnetic tape and video tape for subsequent processing.

4.2 Radar Sensitivity Considerations

The output signal to noise ratio of the 95 GHz radar is heavily dependent upon the antenna used in the measurements and the receiver sensitivity. In order to minimize the amplitude and phase variation across the target, large beamwidths are desired but to

Figure 7

DATA COLLECTION LOG

DATE: TAPE NO:		SITE CONDITIONS							CONSTANT PARAMETERS PULSE WIDTH:			
RUN NO:	TEST DESCRIPTION	TIME START STOP	RANGE	TARGET	ASPECT	CLUT-TER	DEP∠	AZ∠	FREQ	BEAM	POL	REMARKS

TABLE 2a

ISOLATED TARGET DATA MEASUREMENTS

Target	Range	Clutter Type	Beamwidth	Polarization	Aspects	Data Runs
Tank	250m	(Grass)	3^{o}	H/V, R/L, R	10	30
	450m	"	0.7^{o}	H/V, R/L, R	10	30
Truck	250m	"	3^{o}	H/V, R/L, R	10	30
	450m	"	0.7^{o}	H/V, R/L, R	10	30
Auto	250	"	3^{o}	H/V, R/L, R	10	30
	450	"	0.7^{o}	H/V, R/L, R	10	30
Trihedral	250	"	3^{o}	H/V, R/L, R	1	6
$10m^2$, $1m^2$	450	"	0.7^{o}	H/V, R/L, R	1	6
2 Trihedrals	250	"	3^{o}	H/V, R/L, R	"2"	6
100 m^2 ea.	450	"	0.7^{o}	H/V, R/L, R	"2"	6
Dihedral &						
Trihedral	250	"	3^{o}	H/V, R/L, R	"2"	6
$\sim$ 100 m^2 ea	450	"	0.7^{o}	H/V, R/L, R	"2"	6
				Total Table 2a.		216

TABLE 2b

CLUTTER DATA MEASUREMENTS

Clutter	Range	Beamwidth	Polarization	No. Sites	Data Runs
Grass	250	3°	H/V, R/L, R	2 sites	6
	250	0.7°	H/V, R/L, R		6
	450	3°	H/V, R/L, R	2 sites	6
	450	0.7°	H/V, R/L, R		6
Trees	250	18°	H/V, R/L, R	2 sites	6
	250	3°	H/V, R/L, R	2 sites	6
	450	0.7°	H/V, R/L, R	2 sites	6
	450	3°	H/V, R/L, R	2 sites	6
	900	0.7°	H/V, R/L, R	2 sites	6
	900	3°	H/V, R/L, R	2 sites	6
Tree Line	450	3°	H/V, R/L, R	2 sites	6
	450	0.7°	H/V, R/L, R		6
			Total Table 2b.		72

TABLE 3

TARGET/CLUTTER DATA MEASUREMENTS

Target	Clutter	Range	Beamwidth	Polarization	Aspects	Data Runs
Tank	Grass	450m	3^{o}	H/V, R/L, R	8	24
	Trees		3^{o}	H/V, R/L, R	8	24
	Tree Line		3^{o}	H/V, R/L, R	8	24
	Grass	250m	18^{o}	H/V, R/L, R	8	24
	Trees		18^{o}	H/V, R/L, R	8	24
Truck	Grass	450	3^{o}	H/V, R/L, R	8	24
	Trees		3^{o}	H/V, R/L, R	8	24
	Tree Line		3^{o}	H/V, R/L, R	8	24
Auto	Grass	450	3^{o}	H/V, R/L, R	8	24
	Trees		3^{o}	H/V, R/L, R	8	24
	Tree Line		3^{o}	H/V, R/L, R	8	24
Trihedral	Grass	450	3^{o}	H/V, R/L, R	1	6
$1m^2, 10m^2$	Trees		3^{o}	H/V, R/L, R	1	6
	Tree Line		3^{o}	H/V, R/L, R	1	6
				Total Table 3		232
				Total All Meas.		570

improve S/N, smaller beamwidths are required. The radar receiver has a 1 GHz IF bandwidth, a 7 MHz video (post deteriation) bandwidth, and mixer noise figure of 10 dB (DSB). The resulting sensitivity is approximately -81 dbm. The antenna requirements to meet a desired 3 dB or 1 dB amplitude taper across a target 10 meters in length are shown in Table 4. The table gives the minimum range for which the antenna meets the 3 dB or 1 dB requirement. Table 5 is the output S/N ratio of the receiver (single pulse) with respect to a 1 square meter target as a function of range and antenna size. Consequently, on a single pulse basis, the measurements will require the use of the 0.7° antenna at 900 meters, the 3° and 0.7° antennas at 460 meters and the 3° and perhaps the 18° antenna at 250 meters. In addition, for the clutter measurements the same antennas will be required based on the beam intercept area (A_b) noted in Table 5 and an experted to $\sigma^{o} = -20m^2/m^2$. (This results in a $\sigma^{o} A_b \simeq 1$ square meter).

4.3 Radar Calibration

The 95 GHz radar calibration will be performed before and after each segment of measurements or at the beginning and ending of each day. The receiver transfer function is determined by injection of a known signal level into the receiver front end. This level is stepped in 5 dB increments from receiver saturation to the receiver noise level. The transmitter pulse width and peak power level are likewise measured and recorded. The radar is then boresighted on a series of standard reflectors ($1000m^2$, $100m^2$, $10m^2$) and these data recorded on fm tape. All the radar parameters have determined so that the calibration of the standard target and the injected signals should give predictable results. Departure from these values indicates a problem which must be resolved prior to taking data measurements. The recorded calibration allows the backscatter data from the targets and clutter to be calibrated in terms of radar cross section. The phase detectors are calibrated in laboratory measurements, however the limits of the detectors ($\pm 90^{\circ}$) are established by the measurement of trihedral and diplane reflectors, and recorded during the measurements.

4.4 Recording Data Format

The analog boxcarred data, at the radar prf rate (4882 hertz) will be recorded on fm magnetic tape using a Honeywell 5600 recorder. The tape will be recorded at 15 1/2 ips in a wideband format. This combination provides a 10KHz frequency response. Table 6 is a listing of the tape channels and data to be recorded.

TABLE 4 ANTENNA REQUIREMENTS FOR A 10M TARGET

ANTENNA 3 dB BEAM	RANGE (3dB TAPER)	RANGE (1 dB TAPER)	GAIN
18°	32m	54m	19.5 dB
6°	95m	162m	29 dB
3°	191m	324m	35 dB
1.7°	337m	572m	40 dB
0.7°	818m	1391m	47.5 dB

TABLE 5 SINGLE PULSE S/N

RANGE	ANTENNA BEAM	POWER RECEIVED	S/N ($1M^2$)
900m	0.7°	-52.6 dBm	+28.4 dB
900m	3°	-78 dBm	+3 dB
460m	0.7°	-41 dBm	+40 dB
460m	3°	-66.3 dBm	+14.7 dB
250m	3°	-55.8 dBm	+25.2 dB
250m	6°	-67.8 dBm	+13.2 dB
250m	18°	-86.8 dBm	-5.8 dB

TABLE 6 FM TAPE RECORDER CONFIGURATION

SPEED: 15ips WIDEBAND II FREQ. RESPONSE: 10KHz

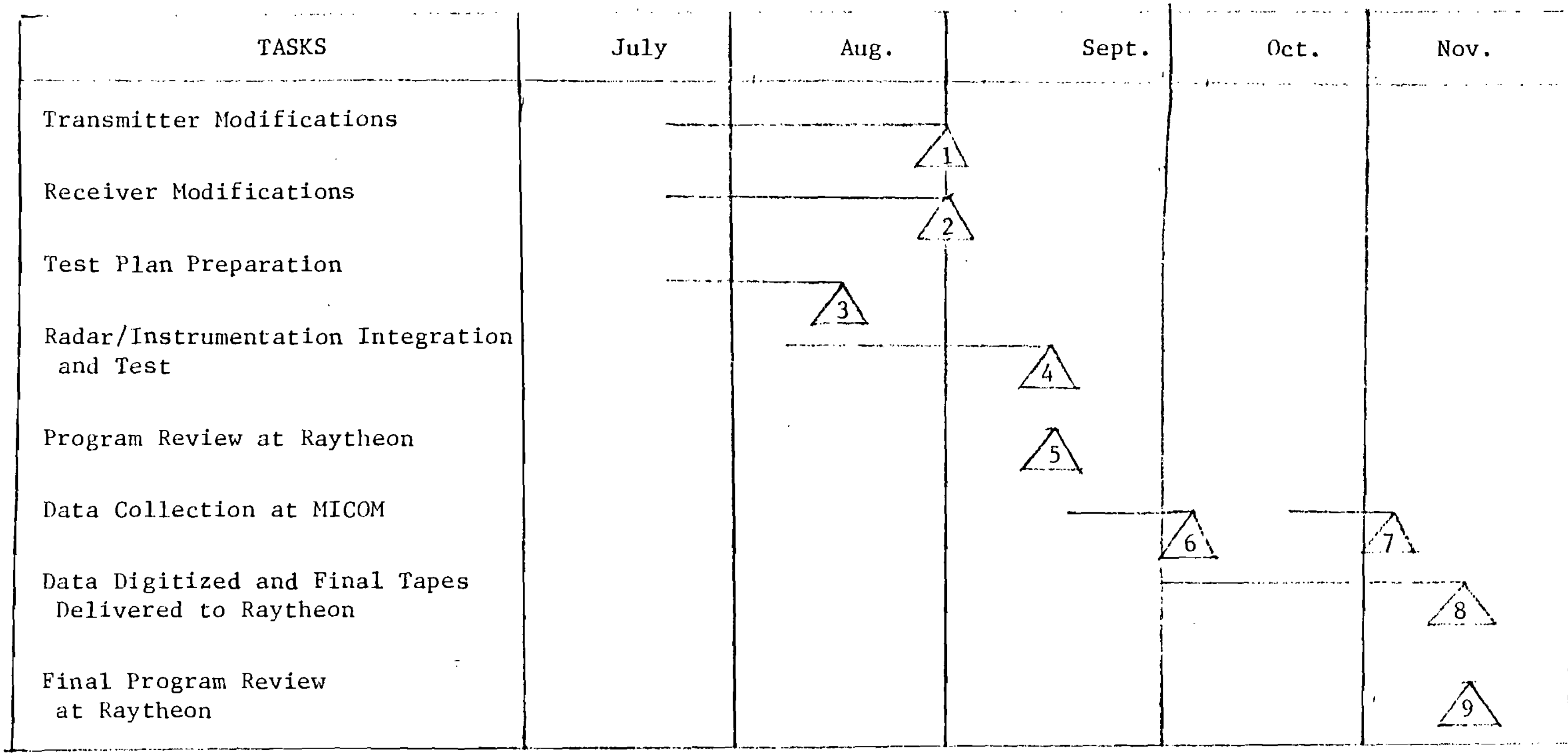
Channel No.	Description
1	Horizontal Amplitude
2	Vertical Amplitude
3	I - Polarimetric Phase
4	Q - Polarimetric Phase
5	PRF Reference (Polarization Ref.)
6	Freq. Agility Reference
7	IRIG-B Time Code
Edge Track	Voice

The format of the digital data tapes to be delivered to Raytheon will be as follows. Georgia Tech will use 1/2 in tape with 8 bits of data and one parity bit (9 track) at a density of 1600 bits per inch BPI. If necessary, Georgia Tech can record 800 BPI. While 12 bits of resolution are available from the A/D converter, only 8 bits need be recorded due to the relatively small dynamic range of the data. The six data words digitized for each PRF interval are transmit polarization, frequency agility sweep voltage, vertical amplitude, horizontal amplitude, and polarimetric I and Q phase. These six word groups will be combined into records of 1024 PRF intervals, or 3072 packed words. Each measurement data run of perhaps 30 seconds of data will become a tape file consisting of approximately 140 records for a PRF of 4.88 kHz. This means about 4 data records per second of measurement data. The first record in each file will contain ASCII characters describing that data run including date, start time, target type, aspect, range, attenuation etc. Besides data runs, the digital tapes will contain enough calibration runs to adequately calibrate the data. Each calibration run will become a data file on the tape with 128 records of 1024 PRF intervals each per RF attenuator setting.

4.5 Schedule

The RADAR preparation and target measurements will be conducted in accordance with the schedule shown in Figure 8.

Figure 8 MILLIMETER RADAR BACKSCATTER DATA COLLECTION



Milestones	Responsible Engineer
1. Transmitter Mods Complete	Butterworth
2. Receiver Mods Complete	Brookshire
3. Test Plan Complete	Bomar
4. Radar & Instrumentation Integration & Calibration Complete	Bomar/Butterworth/Brookshire
5. Program Review at Raytheon	Cash/Bomar
6. Initial Data Collection Complete	Bomar
7. Final Data Collection	Bomar
8. Digital Data Tapes Delivered to Raytheon	Cash/Bomar
9 Final Program Review at Raytheon	Cash/Bomar